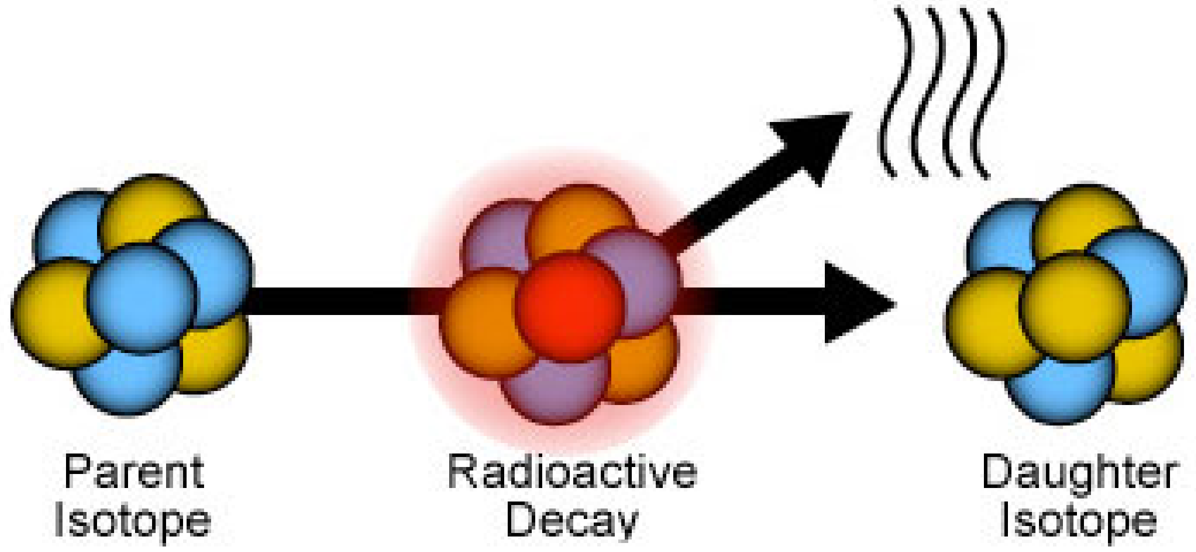


Lecture 12: Model ages

1. Decay chains and half-lives
2. Model ages
    A. Sm-Nd system
    B. Isochrons

We acknowledge and respect the lək̓ʷəŋən peoples on whose traditional territory the university stands and the Songhees, Esquimalt and W̱SÁNEĆ peoples whose historical relationships with the land continue to this day.

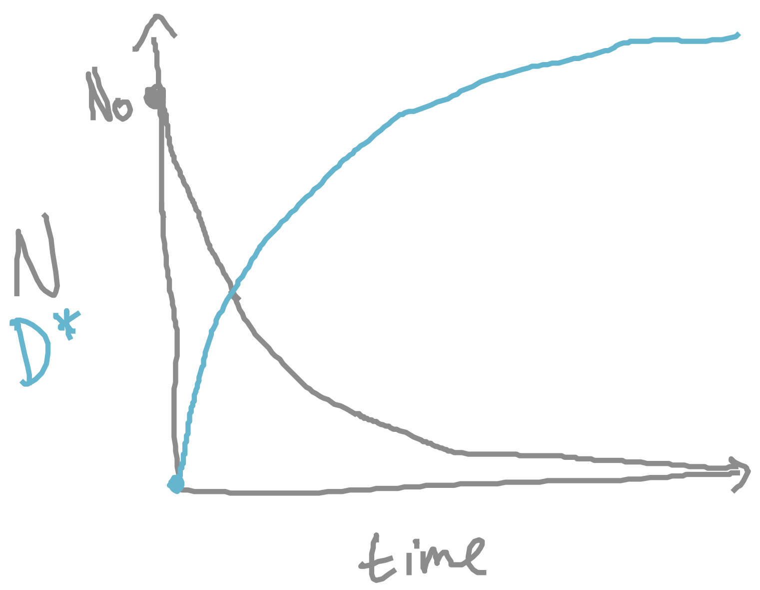
The decay equation.

measurable

$$N_0 e^{-\lambda t} = N$$

not measurable

measurable



N = parent isotope

D = descendant isotope

$$N_0 e^{-\lambda t} = N$$

$$N e^{\lambda t} = N_0$$

reversible

$D^* = N_0 - N$ Descendant created by the decay of N

$D = D_0 + D^*$

initial D

generated D

$D^* = N e^{\lambda t} - N_0 e^{-\lambda t}$ * hard to measure absolute values, so ratio w/ stable isotope common

$D^* = N(e^{\lambda t} - 1)$

measured

$$\frac{D}{X} = \frac{D_0}{X} + \frac{N}{X}(e^{\lambda t} - 1)$$

Half life

Half life

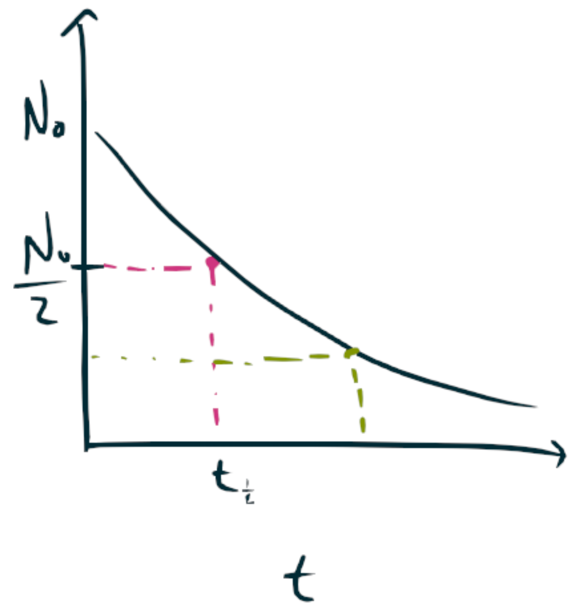
how long does it take for half of N to decay?

$$N = \frac{N_0}{2}$$

$$\frac{N_0}{2} = N_0 e^{-\lambda t}$$

$$\frac{1}{2} = e^{-\lambda t_{\frac{1}{2}}}$$

$$-\frac{\ln \frac{1}{2}}{\lambda} = t_{\frac{1}{2}}$$



large decay constant means short half life

Decay chains

Consider

$A \rightarrow B \rightarrow C$

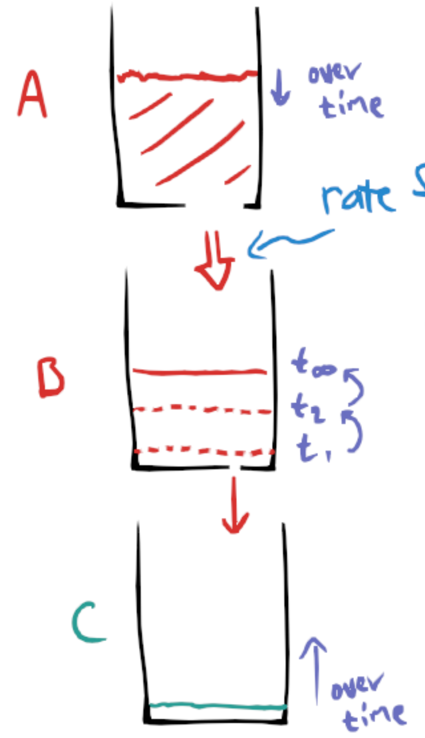
unstable, unstable, stable

$$\frac{dN}{dt} \propto N$$

$$\frac{d\,^{238}U}{dt} = -\,^{238}\lambda\,^{238}U$$

$$\frac{d\,^{234}U}{dt} = \,^{238}\lambda\,^{238}U - \,^{234}\lambda\,^{234}U$$

$$\frac{d\,^{230}Th}{dt} = \,^{234}\lambda\,^{234}U - \,^{230}\lambda\,^{230}Th$$

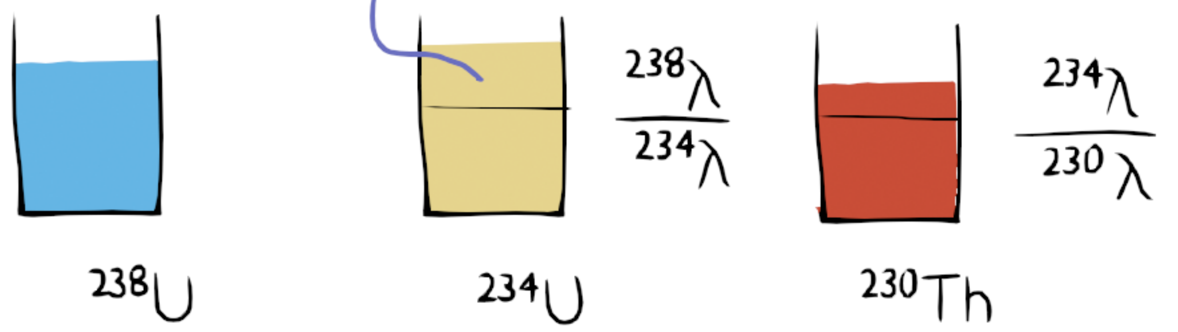


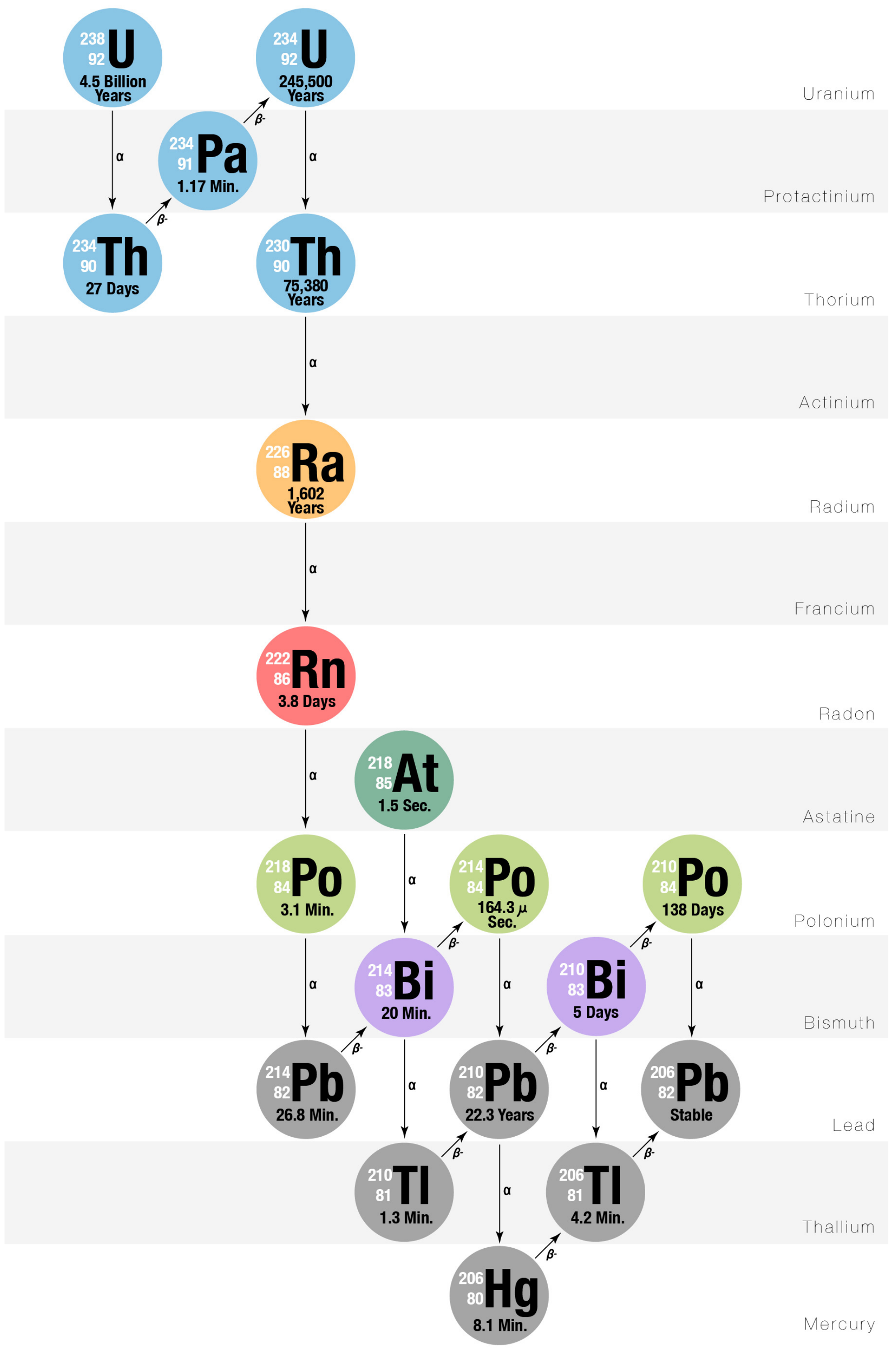
eventually enough B that $\frac{dB}{dt} = 0$

$$\frac{d\,^{234}U}{dt} = \frac{d\,^{230}Th}{dt} = 0 \quad \text{at steady state}$$

$$\frac{^{238}\lambda}{^{234}\lambda} = \frac{^{234}U}{^{238}U}$$

Modern seawater not in secular equilibrium





238 92 U 4.5 Billion Years
234 92 U 245,500 Years
234 91 Pa 1.17 Min.
234 90 Th 27 Days
230 90 Th 75,380 Years
226 88 Ra 1,602 Years
222 86 Rn 3.8 Days
218 85 At 1.5 Sec.
218 84 Po 3.1 Min.
214 84 Po 164.3 μ Sec.
210 84 Po 138 Days
214 83 Bi 20 Min.
210 83 Bi 5 Days
214 82 Pb 26.8 Min.
210 82 Pb 22.3 Years
206 82 Pb Stable
210 81 Tl 1.3 Min.
206 81 Tl 4.2 Min.
206 80 Hg 8.1 Min.
α
β-
Uranium
Protactinium
Thorium
Actinium
Radium
Francium
Radon
Astatine
Polonium
Bismuth
Lead
Thallium
Mercury

$^{147}Sm \longrightarrow {}^{143}Nd$

half life 105 billion years

* isotope ratio more meaningful than absolute abundance, so we divide by a stable isotope

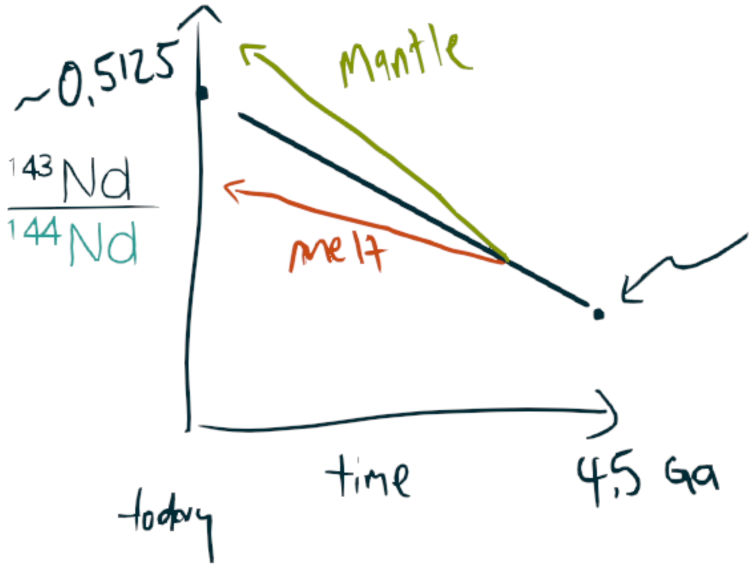
$$\underbrace{\left(\frac{^{143}Nd}{^{144}Nd}\right)}_{\text{today}} = \underbrace{\left(\frac{^{143}Nd}{^{144}Nd}\right)_0}_{\text{initial}} + \underbrace{\left(\frac{^{147}Sm}{^{144}Nd}\right)}_{\text{today}}\left(e^{\lambda^{147} t} - 1\right)$$

Sm, Nd are RLE

What happens when we melt the mantle? Sm, Nd incompatible

Nd more incompatible

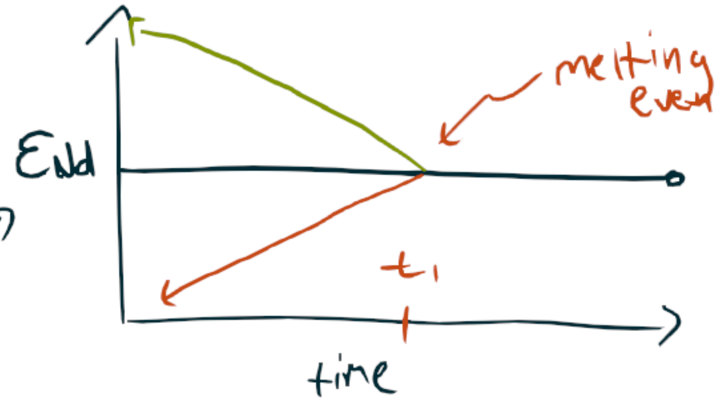
melt $\frac{Sm}{Nd}$ lower than solid



chondritic ratio evolution

(~ Primitive Mantle)

lab5



melting event with model age t_1

Isochrons

how much Descendant isotope does our sample start with?

↳ how do determine the age of a sample if we don't Know D_0?

Partition coefficients for N

$D^N_A = 4$

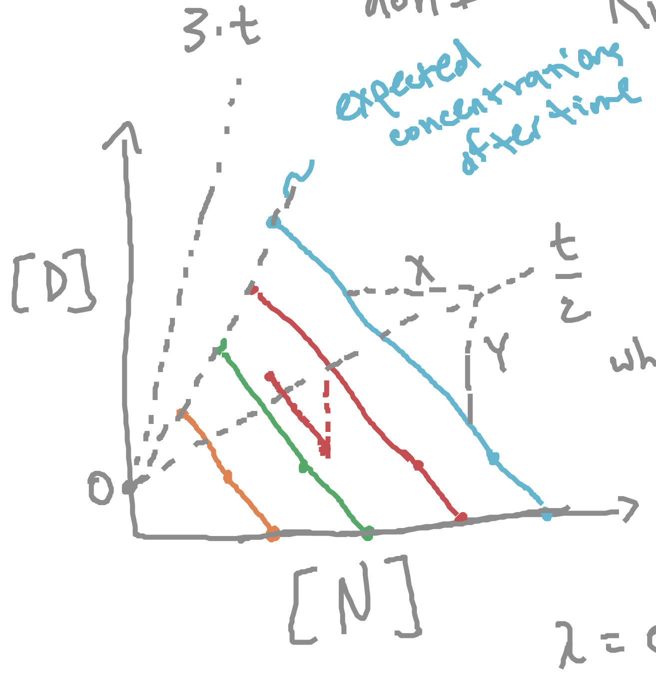
$D^N_B = 3$

$D^N_C = 2$

$D^N_D = 1$

$D^D_D = 0$

$N \rightarrow D$



$D = D_0 + N(e^{\lambda t} - 1)$

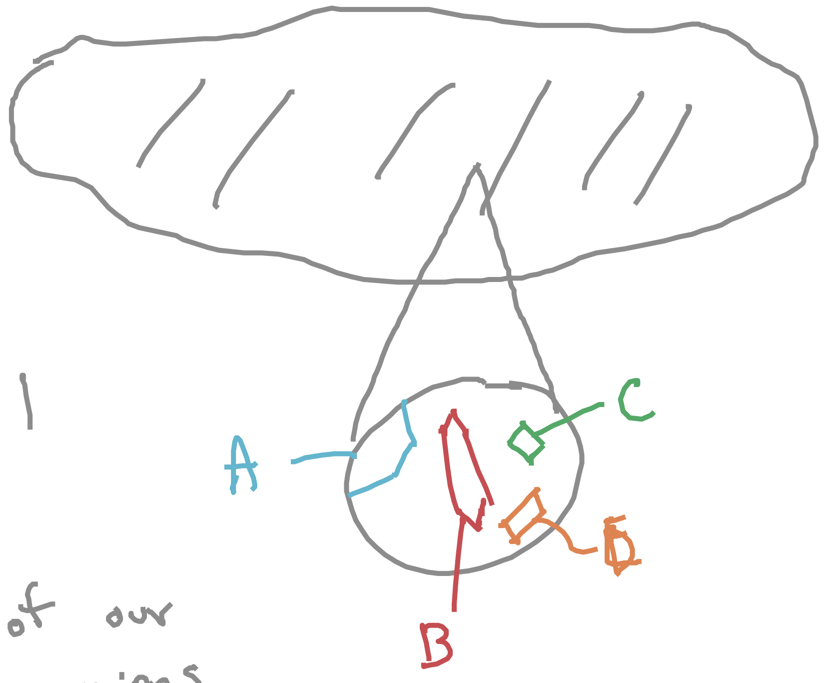
↑
0

$Y = B + xM$

what is $\frac{x}{Y}$? slope of 1

$\lambda = 0.01$

isochrons: the slope of our sample observations is a function of time



if $m = 10$

$10 = e^{\lambda t} - 1$

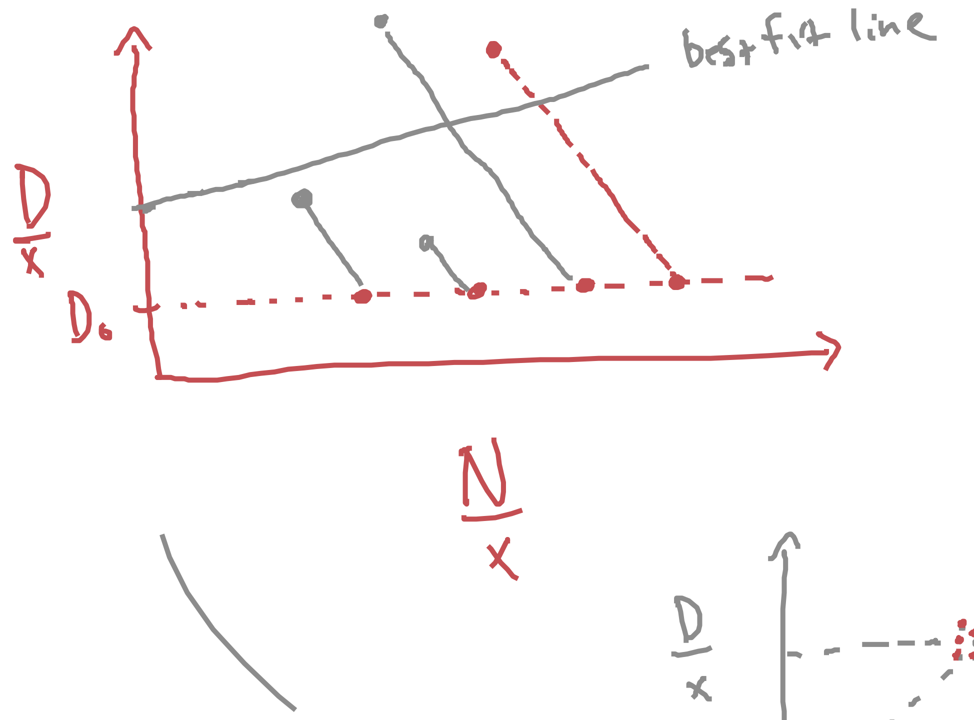
$11 = e^{\lambda t}$

$\ln 11 = \lambda t$

$\ln e^x = x$

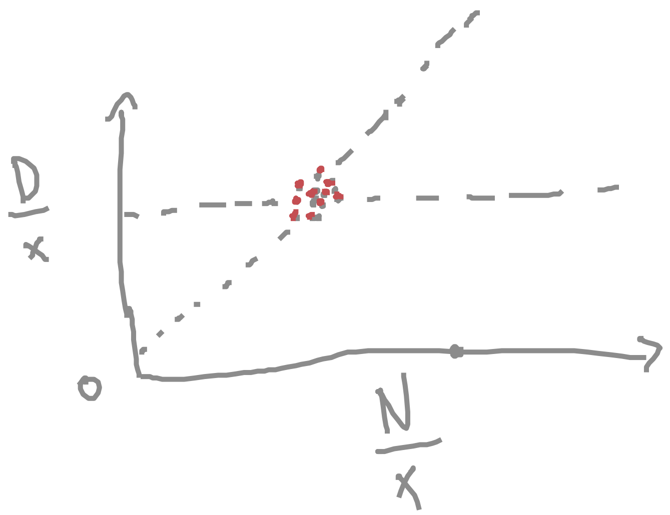
Isochrons

if a suite of samples forms a line in $\frac{D}{N}$, then the samples <u>may</u> have the same age and initial D_0.



to use an isochron:

1. Samples have same age
2. Samples have the same initial Descendant isotope
3. D and N isotopes do not enter or leave the mineral or rock since formation (closed system)



it helps when the samples have very different N concentrations